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RADIO WAVE ABSORBING THERMALLY CONDUCTIVE SHEET

TECHNICAL FIELD

The present invention relates to a thermally conductive sheet for absorbing radio wave, more particularly to a structural improvement for removing heat or noise in an electronic circuit.

BACKGROUND ART

Various apparatuses such as computers, household electric appliances, automobiles, and industrial components are provided with electronic circuits using semiconductor devices for controlling respective functions of those apparatuses. A circuit of further high speed processing performance has been invented by digitizing the electronic circuits. Along with this trend of higher speed processing, it is required to prepare countermeasures for radiated noise to surroundings, or for noise due to radio wave interference in an electronic equipment in which interference by electromagnetic wave generated itself occurs. Furthermore, since a temperature of semiconductor devices such as CPUs rises high, heat dissipation measures of such devices have come to have significance than ever.

Accordingly, as a conventional countermeasure for noise includes, as disclosed in Japanese Patent Laid-open Publication No. 7-212079, for example, a radio wave absorber obtained by laminating an insulating soft magnetic body layer on a surface of a electrically conductive support, and further

forming a dielectric layer on a surface of the insulating soft magnetic body layer. The insulating soft magnetic body layer is obtained by hardening soft magnetic powder with an organic binder. The radio wave absorber is to be placed on a semiconductor or the like, noise from which is to be suppressed.

A heat dissipation measure, as disclosed in Japanese Patent Laid-open Publication No. 9-111124, for example, includes a thermally conductive silicon rubber composition containing 40-90 wt% of a thermally conductive filler including 10-90 wt% of silica fine powder of 0.1-50 μm in mean particle diameter and 90-10 wt% of alumina fine powder of 0.1-5 μm (except 5 μm) in mean particle diameter. The silicon rubber in which the composition is set by a setting mechanism of an addition reaction setting type or a condensation reaction setting type is adapted to be attached to a semiconductor device or the like which requires heat dissipation.

However, the inventions disclosed in Japanese Patent Laid-open Publication No. 7-212079 or No. 9-111124 were not optimal for both a countermeasure for radiating noise or interference in a cabinet and heat dissipation measure of semiconductor devices.

Namely, according to the invention of Japanese Patent Laid-open Publication No. 7-212079, there exists difficulty in attachment to a semiconductor device such as CPUs which requires heat dissipation measure, since sufficient thermal conductivity is obtained while a certain countermeasure for noise can be provided. On the other hand, according to the

invention of Japanese Patent Laid-open Publication No. 9-111124, reduction of radiated noise by absorption of radio wave is not expected, since the filler in silicon does not contribute to absorption of radio wave.

The present invention was made in view of the above background, and one object thereof is to solve the above problems and to provide a radio wave absorbing thermally conductive sheet having radio wave absorbing performance required as a countermeasure for noise against semiconductor devices and high thermal conductivity for absorbing heat generated at semiconductor devices or the like and transfer it to an external system.

DISCLOSURE OF THE INVENTION

In order to achieve the above and other objects, a radio wave absorbing thermally conductive sheet according to the present invention comprises a soft sheet formed through mixing soft magnetic powder into silicon resin. According to this construction, high complex permeability ($\mu'-j\mu''$) is obtained for a wide frequency range of DC to 20GHz by means of the soft magnetic powder filled in the silicon resin. Specifically, an imaginary part (μ'') of the complex permeability increases for a range of 100MHz to a few GHz.

The imaginary part (μ'') of the complex permeability is proportional to a resistance component (R) of a high-frequency impedance, and electromagnetic energy becomes more susceptible to conversion into heat as the imaginary part (μ'') increases. Thus converted to heat, a radio wave is absorbed.

Moreover, thermal conductivity and heat resistance of a silicon resin are higher than those of other resins. According to the sheet of the present invention, thermal conductivity becomes higher than that of simple silicon resin by mixing with soft magnetic powder which has higher thermal conductivity than that of organic substance.

Therefore, when the radio wave absorbing thermally conductive sheet is contacted to a surface of an object component such as a semiconductor device or the like, heat generated from the article is absorbed by the thermally conductive sheet, transferred in the sheet, and released to an external system. For example, insertion of the thermally conductive sheet between a heat radiating component such as a heat sink and the object component increases efficiency in transferring the heat generated from the object component to the heat radiating component and improves effect of heat dissipation.

Also, radio wave noise radiated from the object component is absorbed into the radio wave absorbing thermally conductive sheet, thus the noise neither leak to the outside nor cause internal reflection. Of course, radio wave noise from the outside is absorbed by the radio wave absorbing thermally conductive sheet, interference of noise in the object component is suppressed.

Furthermore, the sheet of the invention comprises a soft sheet, thus in case that the thermally conductive sheet of the present invention is contacted to a surface of an object component as pressed toward the surface, the surface, i.e.,

an adhesive surface of the soft sheet is deformed according to a surface shape of the component and the sheet is closely adhered to the object component. Therefore, thermal resistance at a contact surface is low, and the above-mentioned heat dissipation effect with heat absorption is significantly enhanced. This effect also corresponds to absorption of radio wave noise.

At least one of ferritic soft magnetic powder and metallic soft magnetic powder may be employed as the soft magnetic powder. This construction improves thermal conductivity. In case that the ferritic soft magnetic powder is used, it is effective where insulation characteristics is required since volume resistivity reaches $10^{11}\Omega\cdot cm$ or more. In this case, reflection of a radio wave decreases since a dielectric constant becomes small. In case that the metallic soft magnetic powder is used, reflection of a radio wave increases due to smaller volume resistivity than that of the ferritic soft magnetic powder. Therefore, appropriate material may be selected according to a required specification and so on.

It is preferable that the metallic soft magnetic powder comprises one or more among permalloy, sendust, silicon steel, Permendur, pure iron, and magnetic stainless steel, and the powder comprises spherical or flat-shaped particles.

Magnetic permeability of the metallic soft magnetic powder is higher than that of the ferritic soft magnetic powder and a particle shape of the metallic soft magnetic powder is easy to control, thus the radio wave absorbing thermally

conductive sheet is able to demonstrate a further higher imaginary part (μ") of complex permeability for a predetermined frequency range. Specifically in case of the flat-shaped particles, orientation of the flat-shaped particles of the metallic soft magnetic powder in a surface direction of the sheet suppresses effect of a demagnetizing field in the surface direction, thus high imaginary part (μ") is obtained at a predetermined frequency.

Moreover, it is preferable that the surface of the soft sheet is adhesive. This construction enables attachment of the sheet to a surface of the object component without adhesives by means of adhesion of the silicon resin itself. Omission of the adhesives enables direct contact of the thermally conductive sheet to the object component which is a source of noise generation on a circuit board, thus noise absorbing performance is improved.

Furthermore, it is preferable that the soft sheet is provided to both sides or one side of a electrically conductive sheet. According to this construction, presence of the electrically conductive sheet improves a shield effect against a radio wave. It is also effective in case of shielding radiation noise and preventing leakage thereof to the outside. The shield effect is obtained only by means of the electrically conductive sheet. However, this will cause problems such that a reflected wave exerts a bad influence on the object component due to increase of reflection of a radio wave, and the radiation noise from the object component is reradiated at the

electrically conductive sheet.

The electrically conductive sheet includes, for example, metal foil, metal mesh, metal coated resin mesh, electrically conductive nonwoven fabric, electrically conductive woven fabric, resin containing electrically conductive powder such as carbon powder and metal powder.

It is preferable that the electrically conductive sheet comprises soft magnetic metal. This construction improves shield characteristics in a low frequency range for 1MHz or less by means of the above-mentioned electrically conductive sheet in the radio wave absorbing thermally conductive sheet.

Furthermore, it is preferable that nonmagnetic inorganic powder is mixed into the soft sheet. The nonmagnetic inorganic powder includes, for example, Al_2O_3, ZnO, and MnO. The nonmagnetic inorganic powder has higher thermal conductivity than that of silicon resin, thus mixing of these powders into the radio wave absorbing thermally conductive sheet improves thermal conductivity of the sheet.

* Definition of Term

The term, "soft sheet" means a sheet provided with such softness that the sheet deforms elastically when pressed to a surface of an object component and the sheet surface deforms according to a shape of a surface of the object component. It is not required for the sheet to have restoring characteristics so as to recover an original shape thereof when the sheet is detached from the component. For example, according to a rubber hardness scale, those of 50 or less are

applicable. Of course, the rubber hardness is merely an exemplified standard. A sheet having a rubber hardness beyond 50 may be applicable as far as the above-mentioned characteristics is satisfied.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a perspective view showing a radio wave absorbing thermally conductive sheet according to an embodiment of the present invention;

Fig. 2A is an exploded perspective view of a radio wave absorbing thermally conductive sheet according to a second embodiment of the present invention;

Fig. 2B is a front view showing a second embodiment of a radio wave absorbing thermally conductive sheet according to the present invention;

Fig. 3 is a front view showing a state where a radio wave absorbing thermally conductive sheet according to the present invention is mounted to an electronic circuit;

Fig. 4 is a cross sectional view showing a state where a radio wave absorbing thermally conductive sheet according to the present invention is mounted to another electronic circuit;

Fig. 5 is a diagram showing a part of an experiment result conducted to search an appropriate component for an embodiment

of a radio wave absorbing thermally conductive sheet according to the present invention; and

Fig. 6 is a diagram showing a part of another result of an experiment conducted to search an appropriate component for an embodiment of a radio wave absorbing thermally conductive sheet according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Fig. 1 shows a first embodiment of a radio wave absorbing thermally conductive sheet according to the present invention. As shown in the same figure, the radio wave absorbing thermally conductive sheet 1 of this embodiment, from its external view, is configured by a soft sheet 1A made from a flat sheet piece. This soft sheet 1A is formed by mixing a liquid silicon resin with soft magnetic powder. As soft magnetic powder, ferritic soft magnetic powder or metallic soft magnetic powder may be used, or both may be mixed. As a ferritic soft magnetic powder various kinds such as Mn-Zn base ferrite, Ni base ferrite, and Mg-Zn base ferrite may be used. When Ni base ferrite is used, thermal conduction is mostly improved, and therefore is preferable.

Further, as a mixing ratio, for 100 parts by weight of liquid silicon resin, the mixing amount of soft magnetic powder may be adjusted in a range of 100 parts by weight to 900 parts by weight, and preferably the mixing amount of soft magnetic powder may be 200 parts by weight to 400 parts by weight.

Further, in aim to improve thermal conductivity, nonmagnetic inorganic powder such as Al_2O_3 with high thermal

conductivity may be mixed. It should be noted that, the nonmagnetic inorganic powder is not limited to Al_2O_3, and an oxide powder, such as zinc oxide or copper oxide, or a metal powder with high thermal conductivity may be used.

Furthermore, a surface of the soft sheet 1A is made to have a sticky adhesiveness. In order for the surface to obtain adhesiveness, for example, a silicon resin showing an adhesiveness after curing is selected, or an adding amount of a curing agent (vulcanizing agent) is adjusted.

The radio wave absorbing thermally conductive sheet 1 having the above component, may be formed as a radio wave absorbing thermally conductive sheet with a rubber hardness equal to 50 or less and a thermal conductivity equal to 0.5w/m·k or more, and a heat-resistance equal to 150°C or more.

Fig. 2 shows a second embodiment of the present invention. In this embodiment, soft sheets 1A are attached by sandwiching a thermally conductive sheet 1B, such as a metal foil or a metal mesh, from both sides. When a radio wave absorbing thermally conductive sheet is constructed in this way, noise absorbency and thermal conductivity improve, and it has been confirmed difficult for electromagnetic waves generated from some of the chips of an electronic circuit to spread to other chips and thereby cause electromagnetic interferences within an equipment (malfunction within an equipment).

As the conductive sheet 1B, other than the above, there may be applied such as a resin mixed with a conductive nonwoven fabric, a conductive fabric, or conductive powder, and as

conductive powder, there may be used carbon powder, metal powder, or the like. Further, as these conductive sheets, when a soft magnetic metal or resin mixed with soft magnetic powder is used, its effect improves at a low frequency (1MHz or less).

Next, an actual state of using each radio wave absorbing thermally conductive sheet 1 described above is explained. As one example, as shown in Fig. 3, the radio wave absorbing thermally conductive sheet 1 is arranged on a surface of a CPU 2, and interposed in a space between the CPU 2 and a heat sink 3.

With such a structure, both surfaces of the radio wave absorbing thermally conductive sheet 1, contacting the surface of the semiconductor component such as the CPU 2, and the connecting surface of the heat sink 3, adhere to the respective connecting surfaces closely. Thus, thermal resistance at the connecting part is small, and heat generated by the CPU 2 is efficiently transferred to the heat sink 3 and dissipated.

Further, high frequency noise generated by the CPU 2 is absorbed by the radio wave absorbing thermally conductive sheet 1 adhered as described above, and thus the noise may be suppressed as much as possible from scattering as radiated noise externally.

Fig. 4 shows a state of an electronic component with a case 6 containing a substrate 5 loaded with a semiconductor chip 4, mounted with the radio wave absorbing thermally conductive sheet 1. The radio wave absorbing thermally conductive sheet 1 is a soft flat-shaped sheet and its surface

is made to have adhesiveness, thus when placed between an upper surface 4a of such as the semiconductor chip 4 and the case 6, it is fixed therein. In other words, it is of such a structure that connecting members such as adhesive tapes are not necessary.

Further, by sealing the gap in the case 6 containing the semiconductor chip 4 and the electronic circuit, it becomes easier to suppress interference within the equipment occurring due to an electromagnetic wave generated from a certain semiconductor chip spreading to another semiconductor chip. In particular, since the radio wave absorbing thermally conductive sheet and such as the semiconductor chip 4 are adhered to each other, noise is not transmitted via the gap generated between these components, and transmitting of noise may be suppressed for certain.

Further, when the case 6 is constructed of metal, the case 6 itself displays a function of a heat sink, thus a heat dissipating effect may also be expected. It should be noted that, if the case 6 does not have a function as a heat sink, the heat generated from such as the semiconductor chip 4 is carried in a thickness direction of the radio wave absorbing thermally conductive sheet 1, therefore the generated heat may be suppressed as much as possible from being transmitted to adjoining elements (compared to transmission in the air).

Hereinbelow, manufacturing steps of a radio wave absorbing thermally conductive sheet according to this embodiment are simply described. Liquid silicon resin and soft

magnetic powder are uniformly combined by a mixer. In aim to improve thermal conductivity, Al_2O_3 or the like with high thermal conductivity may be mixed therein.

The mixer performs mixing within a closed stainless chamber by rotating a wing for mixing. At the time of mixing, the inside of the mixer is made to a lower pressure than the atmospheric pressure, and mixing is performed with care so bubbles do not enter into the liquid silicon resin. Further, in a case soft magnetic powder is ferrite, in order to adjust a blend viscosity of a compound formed of liquid silicon resin and ferrite, a temperature of the compound is preferably controlled at 40 to 100°C.

As a mixer, a triple roll mill, a pressure kneader, a biaxial type kneader, and the like may be used. A biaxial extruding kneader may perform continuous kneading and improve productivity, but since dispersion of liquid silicon resin and ferrite powder is not sufficient, it is necessary to perform simple kneading in advance.

After the compound is kneaded it is coated on a PET film with a thickness of 1mm by a doctor blade method. After coating, it is heated and cured to be completed. Further, in order to implement a second embodiment, during coating or after coating by the doctor blade method, a conductive sheet material prepared in advance is sandwiched between coated sheets.

It should be noted that, in a case flat-shaped metallic soft magnetic powder is used, a thickness of one coating is set at 0.1mm or less and laminated. That is, metallic soft

magnetic powder is arranged on a surface direction and then coated to a predetermined thickness. By arranging the powder in the surface direction in this way, a projection area of metallic soft magnetic powder in a thickness direction of the sheet may be largely secured, and the radio wave absorbing function may be improved.

Incidentally, a thermal conductivity of a radio wave absorbing thermally conductive sheet manufactured as described above, when used for an area with a relatively small heat generation, may be 0.5 w/m·k or more, and when applied to a mounting area with a large heat generation, may be 1.0 w/m·k or more, preferably 1.5 w/m·k or more.

*Experiment Results

Fig. 5 shows rubber hardness and thermal conductivity of samples A to D which have different components or mixed quantity, and Fig. 6 shows the radio wave absorbing characteristics of these samples as a coupling attenuation level (dB) between the infinitesimal (very small) antennas for each frequency.

The silicon resin amount in all samples are unified as 100 parts by weight. Sample A includes 400 parts by weight of Mn-Zn base ferrite powder, and sample B includes 600 parts by weight of Mn-Zn base ferrite powder. Sample C includes 300 parts by weight of Mn-Zn base ferrite powder, as well as 100 parts by weight of Al_2O_3 powder. Further, sample D includes 400 parts by weight of Ni-Zn base ferrite powder. However, conductive sheets are not used in any of the above samples.

As shown in Fig. 5, when the content of ferrite powder used as soft magnetic powder is 300 to 400 parts by weight, the rubber hardness is particularly low. It should be noted that, from the experiment results of samples other than those shown in the same figure, in a case the amount of soft magnetic powder is 900 parts by weight or more, it is understood to be difficult to mix it to a resin matrix such as a liquid silicon resin.

On the other hand, in a case soft magnetic powder is 100 parts by weight or less, it is understood that the complex permeability has lowered too much so that a necessary radio wave absorbing property may not be obtained. As described in the explanation showing the manufacturing steps in the embodiment, the mixing quantity of soft magnetic powder in respect to 100 parts by weight of liquid silicon resin is in a range of 100 to 900 parts by weight.

Further, although the rubber hardness of sample C compared to sample A and sample D does not differ considerably, it is known that thermal conductivity of sample C increases more than other samples, by including Al_2O_3 powder which is nonmagnetic inorganic powder. It has been confirmed in various experiments, that by adding nonmagnetic inorganic powder, thermal conductivity may be easily increased to approximately 1.5 w/m·k without decreasing rubber hardness and a coupling attenuation level. It should be noted that, thermal conductivity required by a user who needs a radio wave absorbing thermally conductive sheet such as this embodiment is

approximately 0.5 to 1.5 w/m·k, although depending on the component.

As shown in Fig. 6, when ferrite powder is mixed to each sample as soft magnetic powder, a satisfactory magnetic characteristic in respect to interference within an electronic equipment is seen. As shown in the same figure, in any frequency band of 0 to 1000 (MHz), electromagnetic wave noise is absorbed at a sufficient level for a noise countermeasure of semiconductor chips such as the CPU.

This characteristic is known to show a satisfactory noise absorbing characteristic as a noise countermeasure for an electronic circuit formed of a semiconductor chip or the like such as the CPU. Moreover, electromagnetic energy of the absorbed electromagnetic waves is converted to heat, but since the above samples have a silicon resin as a base material, compared to a radio wave absorbing thermally conductive sheet using other resin, it has higher thermal conductivity and heat resistance.

It should be noted that, in the same figure, the more the amount of soft magnetic powder, the larger the coupling attenuation level, but as described above, by mixing metallic soft magnetic powder, ferrite powder, or the like, and appropriately changing the particle shape, a further satisfactory coupling attenuation level at a particular frequency may be obtained.

INDUSTRIAL APPLICABILITY

As described above, a radio wave absorbing thermally

conductive sheet according to the present invention, with a structure of a soft sheet formed by a silicon resin mixed with soft magnetic powder, when mounted to a semiconductor chip surface with a large heat generation such as the CPU, may improve adhesiveness, and comprise thermal conductivity to efficiently transmit heat externally. Further, with high complex permeability, the radio wave absorbing thermally conductive sheet comprises a radio wave absorbency for absorbing over a broad-band electromagnetic waves within the electronic circuit mounted with a semiconductor element, and may directly absorb electromagnetic wave noise generated from such chip and efficiently convert it to heat to perform a satisfactory noise countermeasure.

As soft magnetic powder, when at least one of ferritic soft magnetic powder and metallic soft magnetic powder is used, in a case ferrite is used, a radio wave absorbing thermally conductive sheet with high thermal conductivity and insulating characteristics is obtained, and in a case metal is used, a radio wave absorbing thermally conductive sheet with high thermal conductivity and high radio wave absorbency is obtained. When metallic soft magnetic powder is at least one or more of permalloy, Sendust, silicon steel, Permendur, pure iron, or magnetic stainless steel, and its shape is spherical or a flat particle shape, a radio wave absorbing thermally conductive sheet with a high electro magnetic wave absorbency of a desirable frequency band is obtained.

When the surface of the soft sheet is made adhesive,

the adhesion of the radio wave absorbing thermally conductive sheet and a semiconductor chip or the like within an electronic equipment to be mounted improves, so that a radio wave absorbing thermally conductive sheet which can transfer heat generated from these chips externally and absorb electromagnetic waves may be obtained. If the soft sheet is provided at both surfaces or one surface of the conductive sheet, a noise shielding characteristic improves.

By structuring the conductive sheet from soft magnetic metal, a shielding effect at a low frequency band is further improved. Further, when the soft sheet is mixed with nonmagnetic inorganic powder, a radio wave absorbing thermally conductive sheet with further improved thermal conductivity is obtained.